Space Solar Power (SSP)
Systems Studies and Analysis

The Aerospace Corporation
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THE AEROSPACE CORPORATION

Aerospace SERT Tasks

- Define innovative concepts, applications, and orbits
  - Work with NASA to define set of SSP concepts to be modeled
- Develop subsystem-level integrated SPS models
  - Enhancement of subsystem models
  - Development of new models, based on chosen concepts and applications
  - Development of up to 5 SPS models, each model for one concept and one application
  - Extended Effort: Development of laser SSP concepts and models
- Conduct subsystem-level trades to "optimize" each SSP system
  - In-depth trade space exploration
  - Determine key system and technology characteristics
- Conduct system-level trades between SSP concepts
  - Compare various SSP concepts for similar applications
- Generation of inputs to investment roadmaps
  - Integrate the requirements of the most promising concepts into a set of technology goals

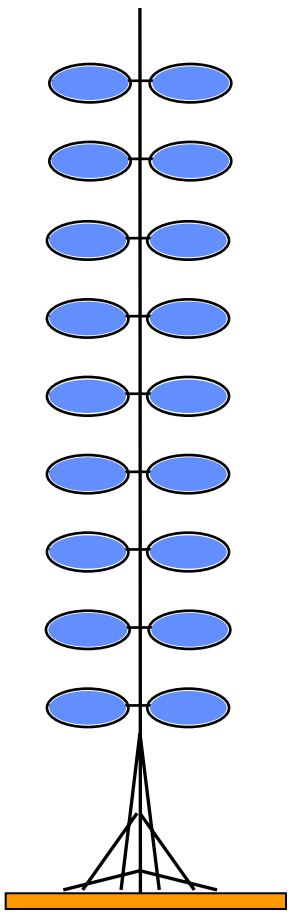
Aerospace SSP Team

Study Lead	Jay Penn
ADACS	Andrei Doran, Jason Ly
Astrodynamics	George Chao
Cost	Vince Canales
Economics	Jay Penn, John Skratt
Ground Systems	Marilyn Dubas
Laser	Renny Fields, Hal Yura
Manufacturing	Susan Ruth
Power Collection / PMAD	Terry Hershey, Ed Berry
Propulsion	Ron Cohen, Jim Pollard, Ed Beiting
Structures	Michael Vanik, John Jai
Systems	Glenn Law, Christopher Taylor
Thermal	Dave Gilmore
TT&C / C&DH / WPT	John O'Donnell, Ed Olson

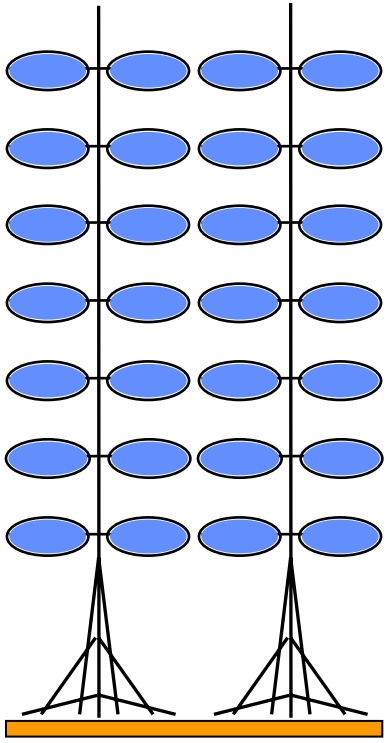
Summary of Aerospace SERT Accomplishments

- Performed detailed modeling on selected SSP concepts
  - Sun Tower concept
  - Multi-Strand Sun Tower concept
  - Perpendicular to Orbit Plane (POP) concept
  - Halo concept
  - Laser concept
  - Microwave demonstrator (MSC-1) concept
  - Laser demonstrator (MSC-1) concept
- Incorporated SSP subsystem model enhancements
  - Enhanced ADACS, Economics, Power, Structures, Thermal, WPT models
  - Developed Cost, Ground System, Manufacturing, Orbit Analysis, PMAD, Propulsion models
- Refined Halo and Laser design, tradespace, related concepts, and applications
- Contribute to WPT, SIWG, and SSP team activities

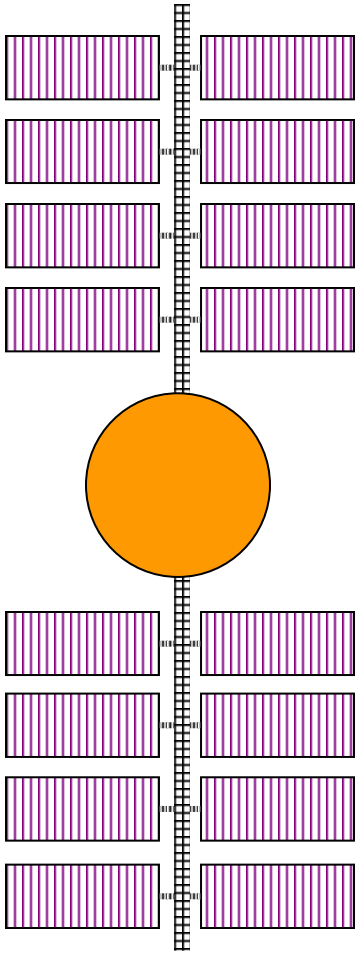
Aerospace SSP Models



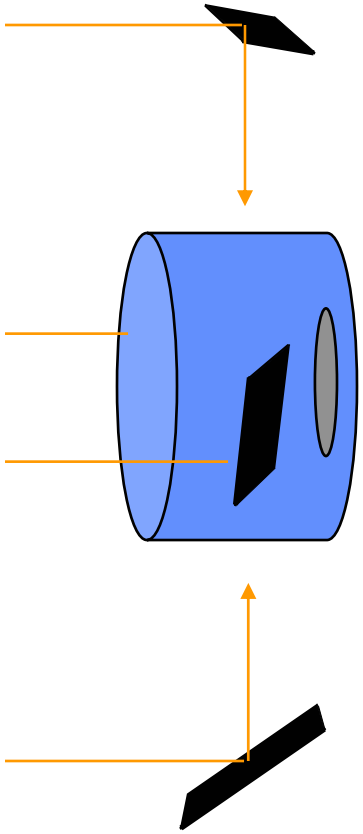
Sun Tower



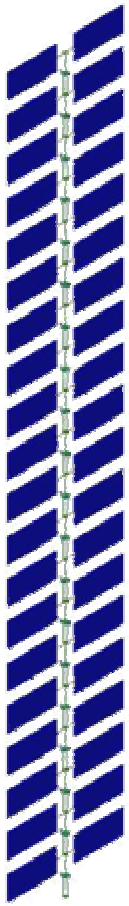
Multi-Strand Sun Tower



POP



Halo



Laser

Not to Scale

Models will be updated on a continual basis

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Aerospace SSP Models -- Mass

(1.2 GW Delivered to Ground)

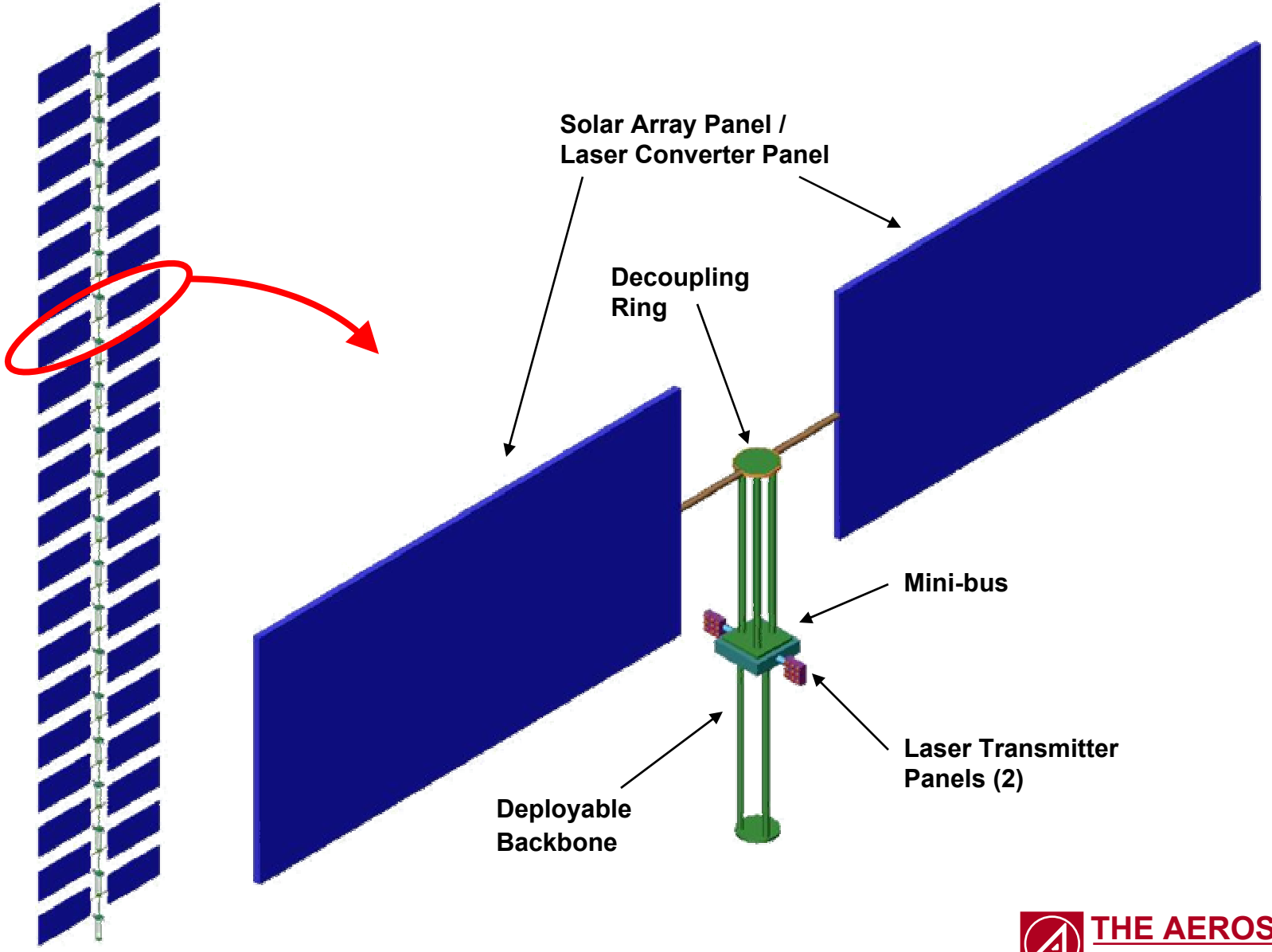
Subsystem	Mass (MT)				
	Sun Tower	**Multi-Strand**	**POP**	**Halo**	**Laser**
Power Transmission	2,840	2,840	2,840	3,068	2.6 / 1,270
Power Collection	4,964	4,964	4,972	3,648	10.0 / 4,784
Attitude Control	170	170	170	58	2.4 / 1,128
Backbone, Tether	7,994	2,385	1,253	43	1.1 / 545
PMAD	6,131	6,117	6,108	5	0.5 / 223
TT&C and C&DH	37	37	37	3	0.5 / 255
Propulsion	3,216	3,217	3,297	2,988	5.2 / 2,499
Thermal	944	944	944	698	0.8 / 390
Robotics	200	200	200	200	0
Dry Mass	**26,497**	**20,874**	**19,820**	**10,712**	**23.1 / 11,094**
On-Orbit Propellant	1,044	1,045	1,434	1,275	0.4 / 180
Transfer Propellant	1,986	1,984	2,059	3,172	6.2 / 2,984
Total Mass	**29,527**	**23,903**	**23,313**	**15,159**	**29.7 / 14,257**

Aerospace SSP Models -- Cost

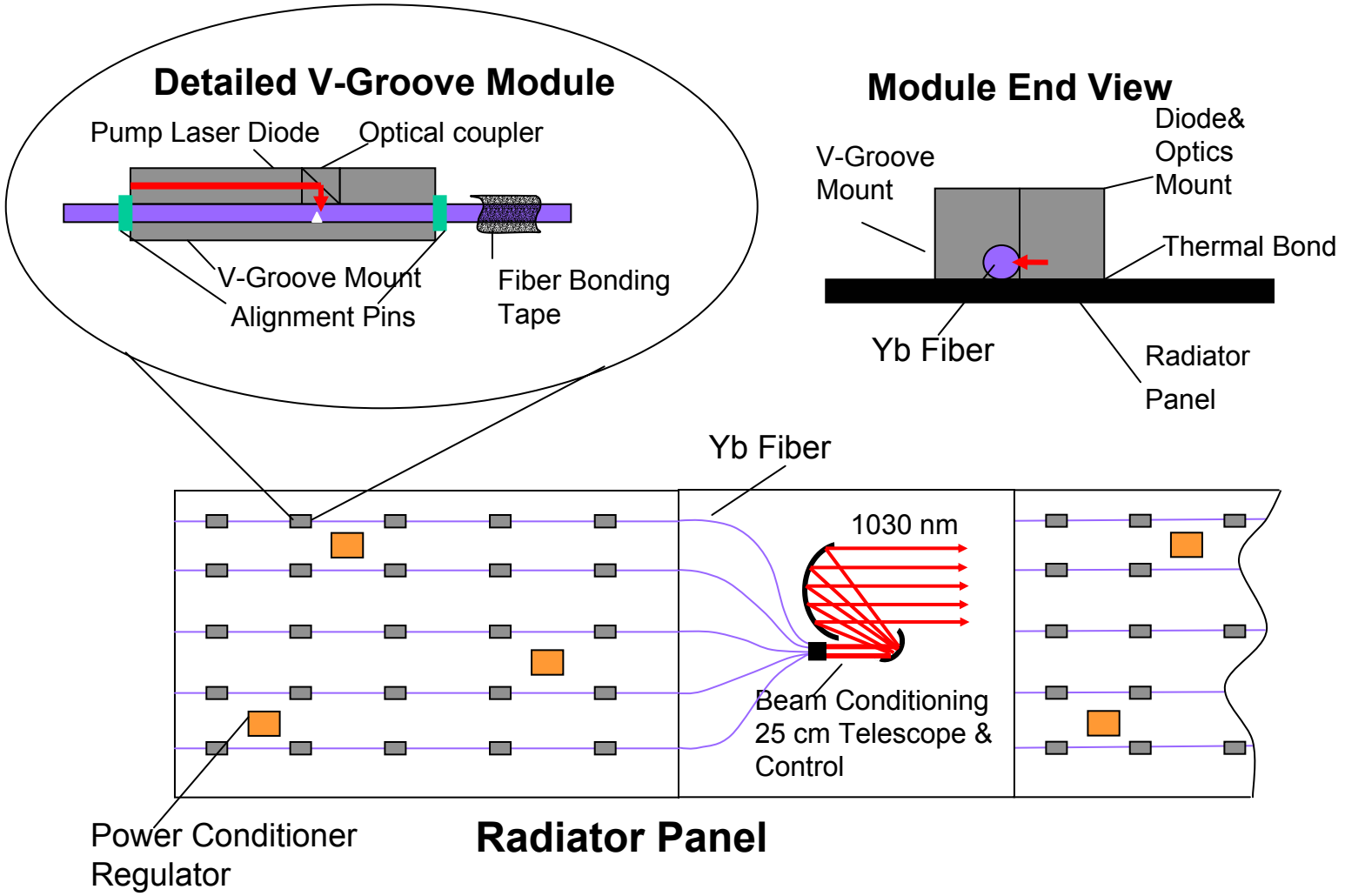
(1.2 GW Delivered to Ground)

Subsystem	Cost ($FY00M)			
	Sun Tower	Multi-Strand	POP	Halo
Power Transmission	1,140	1,140	1,140	1,140
Power Collection	8,447	8,447	8,447	5,752
Attitude Control	505	505	505	53
PMAD	532	320	252	2
TT&C and C&DH	172	172	172	12
Propulsion	7,880	7,881	7,885	5,421
Propellant	1,000	1,000	1,153	1,468
Structure	1,821	1,820	2,524	3,818
Thermal	472	472	472	349
Robotics	200	200	200	200
System AIT&E	3,325	3,294	3,408	2,732
Ground Support Eq.	5,320	5,270	5,453	4,371
Software	516	516	516	516
Program Management	5,464	5,412	5,599	4,491
Spacecraft Cost	**36,794**	**36,450**	**37,695**	**30,324**
Rectenna and Ground	5,156	5,156	5,156	5,156
Launch	12,434	10,067	9,817	6,384
Total System Cost	**54,384**	**51,573**	**52,669**	**41,864**
$/kW-hr for 30% IRR	**$1.08**	**$1.02**	**$1.04**	**$0.83**

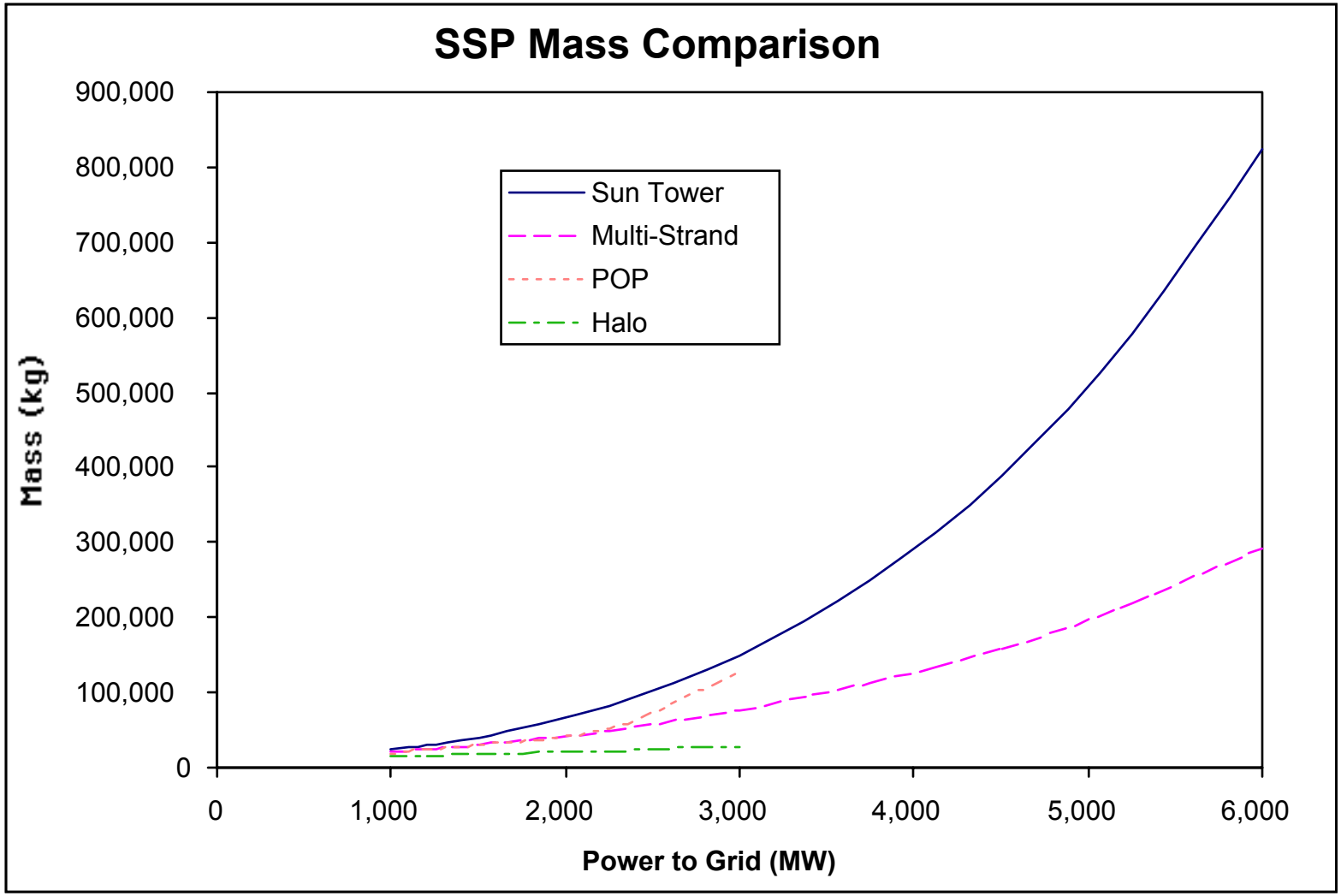
Aerospace Laser SSP Concept



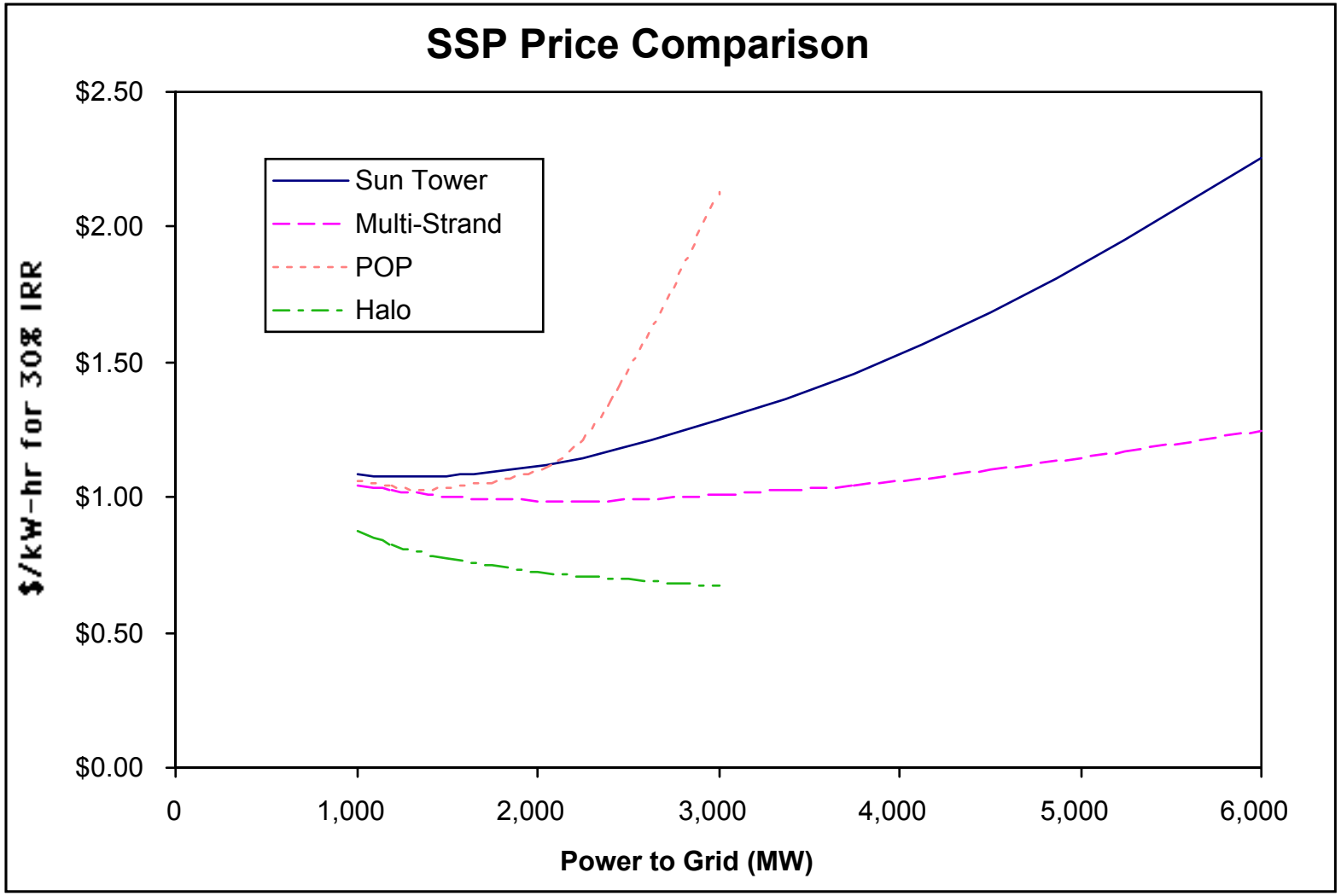
Optical Concept for Laser SSP



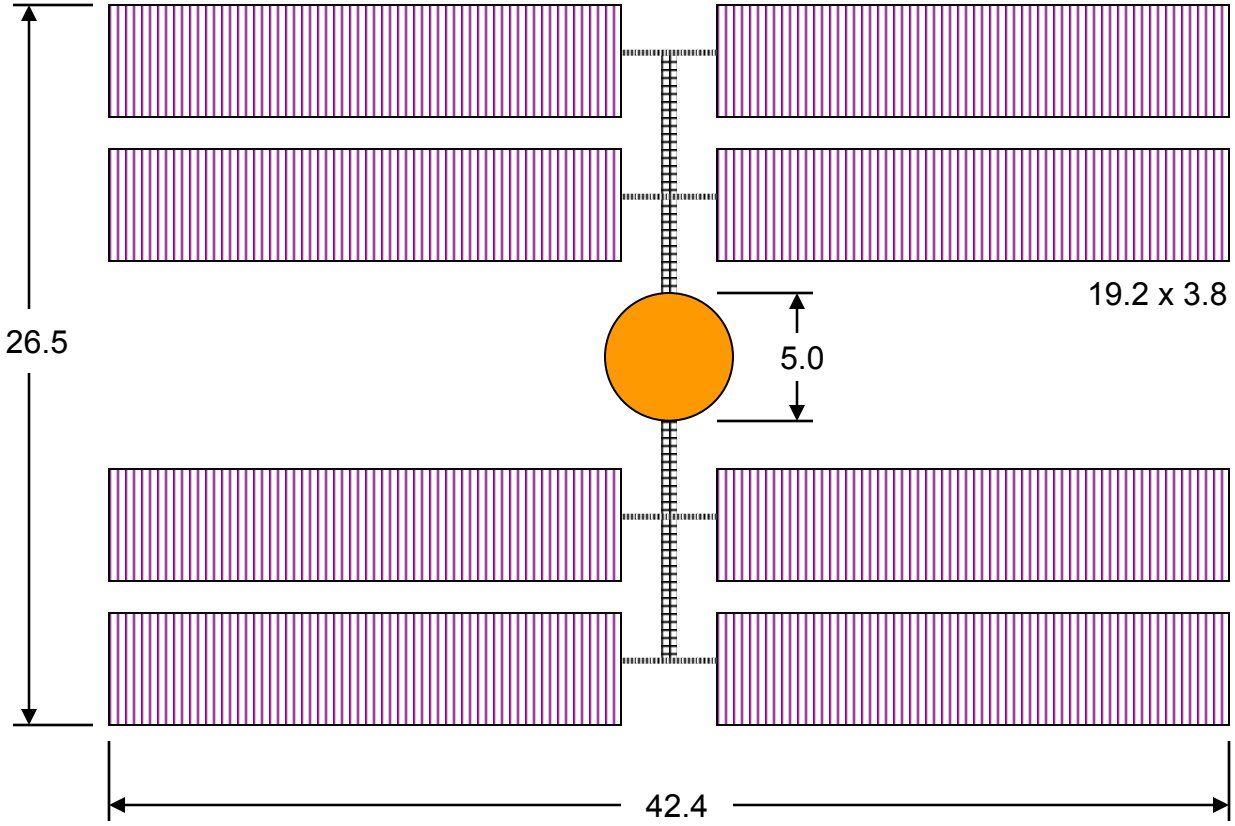
Trade Space Exploration Example



Trade Space Exploration Example



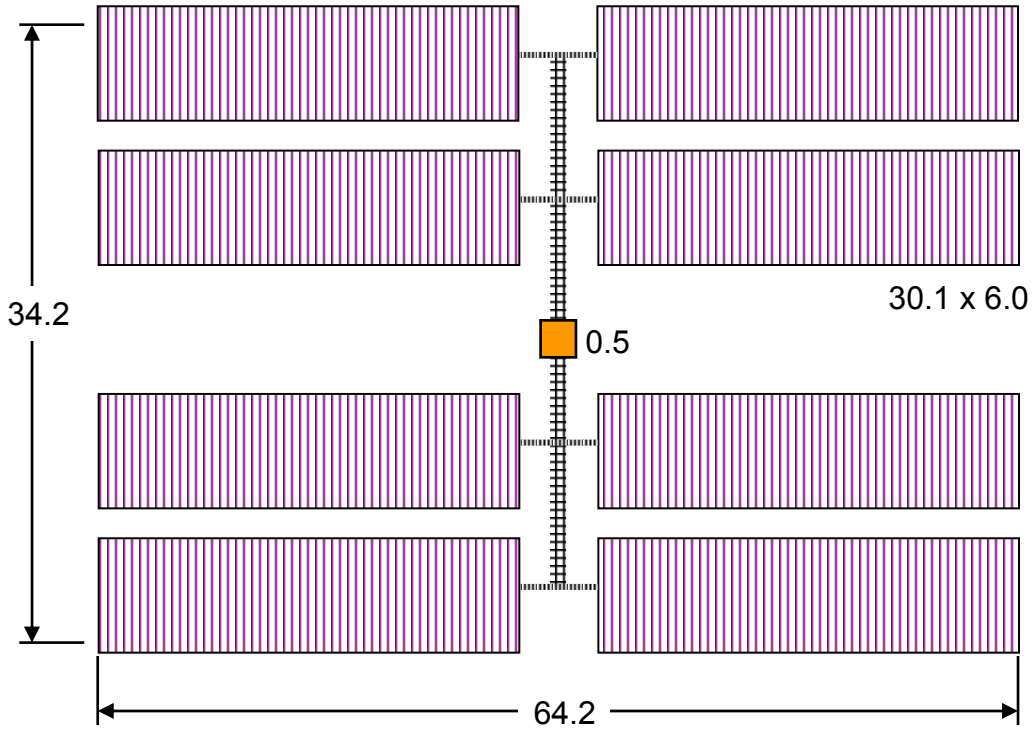
Microwave MSC-1 Concept Model



Subsystem	Mass (kg)
Power Transmission	205
Power Collection	4,413
Attitude Control	157
Backbone, Tether	408
PMAD	3,560
TT&C and C&DH	68
Propulsion	1,284
Thermal	7
Robotics	2,068
Dry Mass	**12,167**
On-Orbit Propellant	506
Transfer Propellant	3,411
Launch Mass	**16,084**

- MSC-1 model is dependent on Mission Delta-V
  - Can be resized to accommodate any science/commercial mission

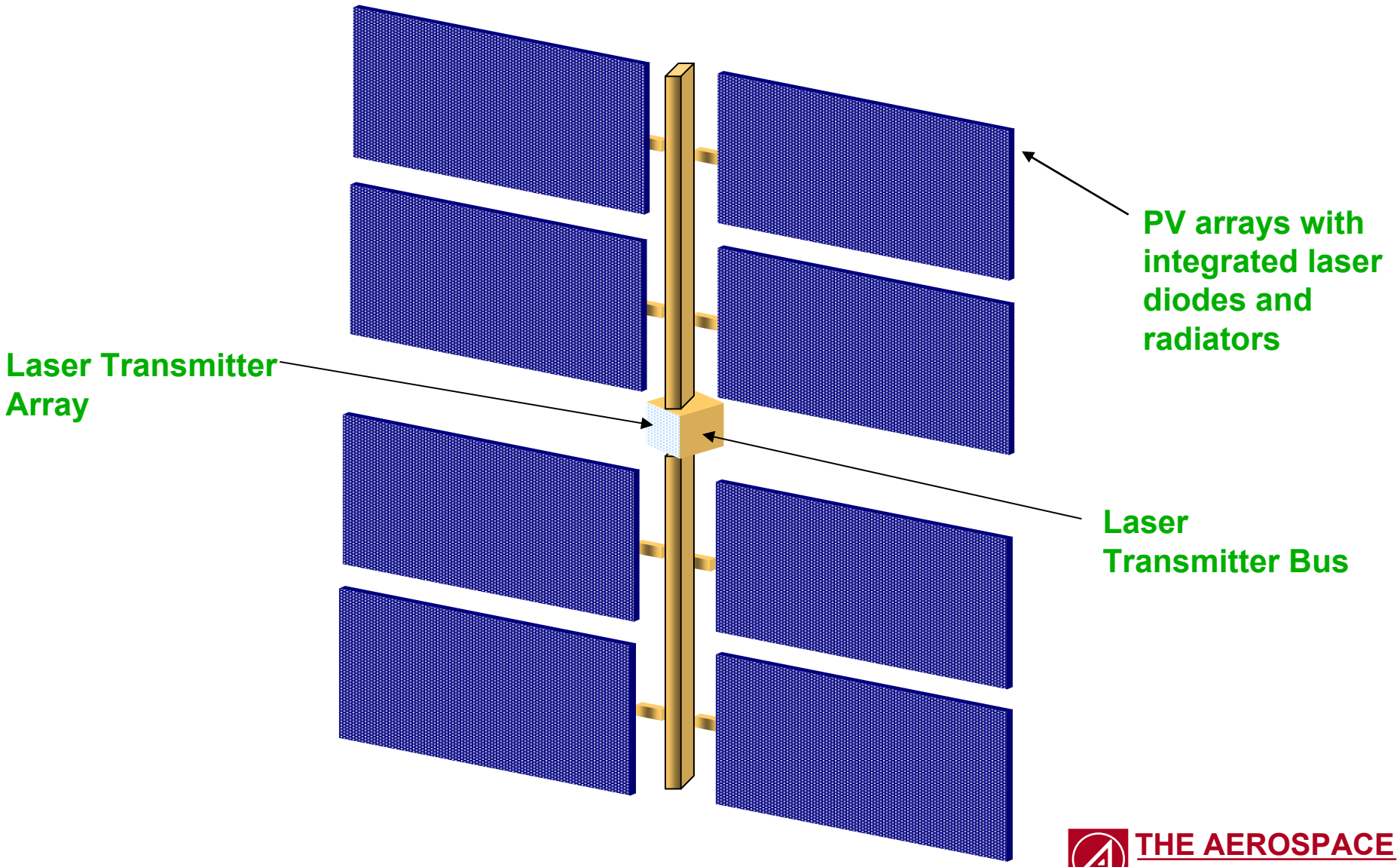
Laser MSC-1 Concept Model



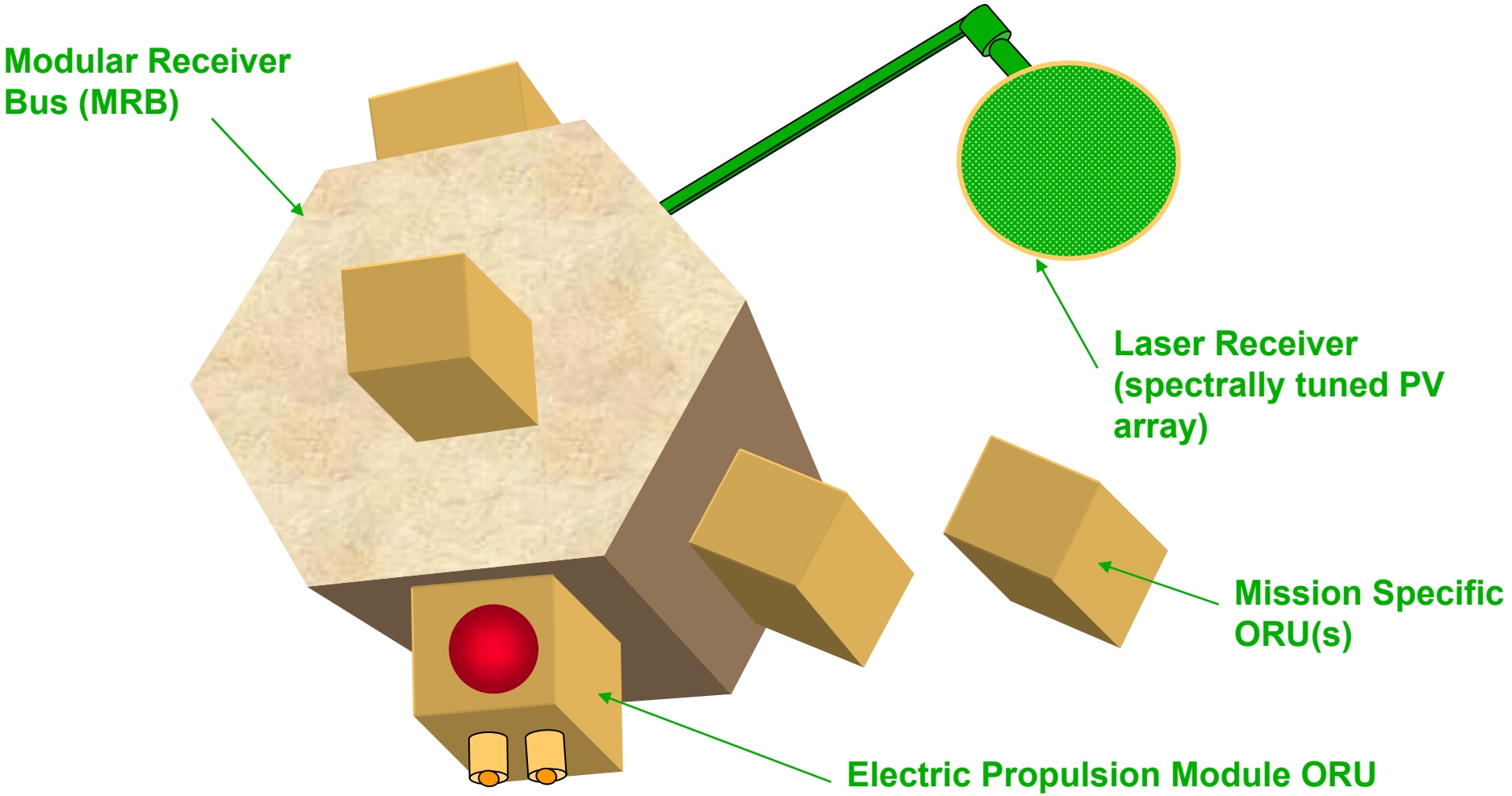
Subsystem	Mass (kg)
Power Transmission	505
Power Collection	6,700
Attitude Control	157
Backbone, Tether	1,023
PMAD	36
TT&C and C&DH	68
Propulsion	1,225
Thermal	424
Structure	1,023
Dry Mass	**11,150**
On-Orbit Propellant	464
Transfer Propellant	3,126
Launch Mass	**14,740**

- MSC-1 model is dependent on Mission Delta-V
  - Can be resized to accommodate any science/commercial mission

Laser Transmitter Bus (LTB) Concept Model



Laser Modular Receiver Bus (MRB) Concept Model



Reference Mission Concept of Operations

1) Deploy and Checkout Laser SSP Transmitter Bus (LTB) and Modular Receiver Bus (MRB) - DARPA NextSat Bus is an option for MRB
2) Demonstration of close proximity WPT from LTB to MRB
   - Provide calibration and characterization of Laser WPT
   - Use Electric propulsion thrusters or other high power device as the load
3) Modular Receiver Bus (MRB) uses electric propulsion to perform separation maneuver(s), vary separation range between 200 and 2000 miles - demonstrates high power EP orbit transfer
4) Beam high power (100 kW class) beam to small diameter (10-12 meter) stationary site - demonstrates power generation for terrestrial SSP
5) Beam moderate power (5-20 kW) to an electrically powered rover mounted with Laser receiver canopy
   -Demonstrate planetary rover (or equipment) powered by orbital power station
6) Use Astro Bus to add Optional Orbital Replaceable Unit (ORU) to MRB
   -Add Mission Kit(s) 1-6 (described on next chart)

CONOPs designed to demonstrate SSP for terrestrial utility, space science/exploration and space industry applications

Potential ORU Mission Kits on MRB

Baseline ORU Kit) - Electric Propulsion Module containing EP thrusters, propellants, and power processing (launched with MRB and occupies one of multiple ORU bays on MRB)

Kit 1) High Power Communications (Commercial, NASA Terrestrial, or NASA Planetary)

Kit 2) Space Based Radar Mission Kit (Military and/or NASA Applications)

- could potentially be a modular, autonomously assembled on orbit, phased array radar

Kit 3) Manufacturing or High Power Experiment Module - allows long duration zero G experiments or manufacture in proximity to ISS

-allows periodic replenishment or recovery of reactants, products, and other consumables either by Astro or by ISS crew/assets

Kit 4) Space Based Laser or SSP Relay Mirror to demonstrate relay of laser energy over long terrestrial distances

Kit 5) Microwave Transmitter Module: demonstrate transmission of 25 to 50 kW of microwave energy to Earth - measure beam pattern to characterize microwave WPT

Kit 6) Microwave Receiver Module: demonstrate high power near proximity (several miles) space-to-space microwave WPT transmission from Microwave SSP Demonstrator

Aerospace JIETSSP Tasks

- Define innovative concepts, applications, and orbits
  - Work with NASA to define set of SSP concepts to be modeled
- Develop/enhance SPS models
  - Enhance SSP concept models
  - Develop new models, based on chosen concepts and applications
  - Conduct subsystem-level trades
- Develop near-term flight demonstrator SPS models
  - Develop specific design details for the SSP demonstrator systems
  - Develop concept of operations for each demonstrator system
  - Conduct subsystem-level trades
- Conduct system-level trades and analysis SSP concepts and architectures
  - Compare various SSP concepts for similar applications
- Develop investment roadmaps based on lessons learned
  - Integrate the requirements of the most promising concepts into a set of technology goals
- Explore and develop synergies with other government efforts